Save your Centrifugal Machinery during Commissioning

ARUN KUMAR
General Manager
Maintenance & Reliability,
Guru Gobind Singh Refinery,
HPCL- Mittal Energy Ltd.,
BATHINDA, INDIA- 151001

MOHIT SABHARWAL
Assistant General Manager,
Maintenance & Reliability
Guru Gobind Singh Refinery,
HPCL- Mittal Energy Ltd.,
BATHINDA, INDIA- 151001

Arun Kumar is currently working with HPCL- Mittal Energy Ltd., India as head of Maintenance & Reliability and is responsible for Maintenance & Reliability of a 11.30 MMTPA high complexity Refinery complex at Bathinda, India. He was earlier responsible for commissioning of mechanical equipment for the refinery, which was completed in record time in Oct' 2011. He has over 31 years of experience in the Hydrocarbon Industry, in Engineering, Reliability & Maintenance, specializing in Rotating Equipment. Arun has extensive experience in the areas of Erection, commissioning, maintenance, troubleshooting and performance improvement of rotating equipment in Process Plant/ World Class Oil Refinery,

Arun is mechanical engineer graduate with post-graduation in business management. He has presented number of technical papers at international venues including the Turbo machinery Symposium

Mohit Sabharwal is AGM, Maintenance & Turnaround Planning in the maintenance & reliability team for HPCL - Mittal Energy limited, Bathinda, India. He is responsible for the reliable operation of a 11.30 MMTPA grass root refinery by supporting Operations. Mohit has commissioned two large refineries in past seven years. He is a mechanical Engineer and has extensive experience in the commissioning, startup & maintenance of grass root refinery plants.

ABSTRACT:

During the commissioning of centrifugal machines (Compressors, steam turbines, pumps, fans etc.), a lack of flushing, inspection and ignorance of critical areas & procedures can lead to major problems, damage, and serious safety issues.

These serious issues and damages lead to a delay in startup of the refinery, resulting in large monetary loss & further delay as major spares required to carry repairs may not be available in initial stage. It is possible to prevent such damage by following the procedures and inspections which are discussed in detail in this paper.

The tutorial covers the experience and learning derived by the commissioning of more than 5,000 rotating machinery equipment over the past 5 years.

The Tutorial will illustrate what can go wrong with centrifugal machinery during commissioning and startup and actual case studies of damage are provided along with the corrective and preventive measures suggested for successful commissioning. A Checklist of Do's and Don'ts to be followed before and during commissioning is also provided.

INTRODUCTION

In the course of a project, the commissioning and startup of centrifugal machines is considered to be the most critical and stressful phase due to the following reasons:

- Startup is the last and very critical event of very long process from conceptualization to capitalization of project investment and can have severe economic impact on the project. For a 9MMTPA refinery, the average estimated production loss per day is approximately 1.7 million USD. Any delay or deviation from plan causes a huge monetary impact.
- Any delay in upstream phases is expected to be compensated by quick and smooth startup of machines. This creates pressure for an early start-up on rotating equipment commissioning engineers.
- Due to involvement of multiple disciplines and extreme pressure for project completion, the probability of mistakes and miscommunications are present.
- As a standard practice two years maintenance spares or commissioning spares and insurance/ capital spares are ordered along with machines. Sometimes, these spares are not sufficient to handle any type of major damage caused due to mishandling of machines and mistakes during commissioning. This can result in startup delay of Units.

Despite of all these potential issues, a safe and smooth start up can be accomplished by following certain procedures, protocols, best practices and maintaining proper communications. This tutorial addresses various probable risks and their mitigation plan at different stages from receipt of equipment at site to successful commissioning and startup of centrifugal machines and details the experiences the authors faced during commissioning of refineries. Various mistakes generally made during different commissioning stages and best practices followed to preserve machinery from any disaster are covered.

What can go wrong in centrifugal Machinery during commissioning?

- Interchange of items of centrifugal machinery package from same vendor causing limitations on start up.
- Damage to turbine internals due to improper steam flushing of steam connected to steam turbines.
- Damage to compressor internals (complete diaphragms, lab seals , rotor)
- Unbalance of rotor assembly caused by entry of external material into suction of machine from piping.
- High vibrations
- Internal rubs & seizures
- Vibrations/ equipment damage due to stresses in connected piping.
- Damage of antifriction bearings in pump due to dust entry in pump bearing housing, in period between erection and startup.
- Vibrations in Hot pumps, seizure.
- High vibrations of driver motors due to soft foot.
- Damage of Hydrodynamic journal bearings and thrust pads & shaft journals bearing due to improper lubrication
- Seal failure in pumps leading to fire.

CASE STUDIES (What can go wrong?):

Some practical case studies related to refinery commissioning providing an insight as to what damages can happen are provided ahead. Also provided are ways to prevent them.

Case Study -1:

A Recycle gas compressor for a hydro-treater in refinery was dispatched for site after a mechanical test run at the OEM shop. Its Dry gas seal was dismantled from shaft and sent as loose item along with the compressor for safe transportation. At the time of installing the dry Gas seal after compressor erection at site, the Dry Gas seal was not traceable in ware house. After extensive search, was located at the construction contractor site store in soiled condition. The vacuum wrap of the gas seal was totally damaged & the seals were highly contaminated with dust particles. The Dry gas seals could not be used and were dismantled, cleaned and refurbished at OEM shop, which was time consuming & involved high cost. Refer Figure 1 & 2 showing soiled dry gas seal

Figures 1 & 2: showing dry gas seals found soiled and bad preservation condition

Lesson Learnt: When Dry gas seals are shipped loose, the box should be taken out from common package of compressor and preserved in an air-conditioned room in the warehouse.

Case Study -2:

Two centrifugal compressors and their drive turbines were sent to refinery by same vendor. One was a wet gas compressor (WGC) for delayed Coker unit (DCU) & its drive steam turbine and other was a Recycle gas compressor (RGC) for diesel hydro-treater (DHDT) &

its drive steam turbine. Both steam turbines were condensing designs, but of different ratings. The condensate pumps of both the turbines were from the same vendor but different in specifications.
After commissioning there was no problem at partial unit loads but at full load, both the turbines exhibited problem.
Problem: For both Steam turbines for WGC of DCU the respective condensate pumps had to run at rated load of steam turbine. As per design one pump was to run with the other as a standby.
Steam turbine for RGC of DHDT: the turbine tripped twice on cavitation of condensate pump as it left the load.
Root Cause: The problem was together studied by the reliability team by examining the data sheets. It was found that during erection condensate pumps of both the subject turbines got swapped as they were from same vendor. The operating conditions are shown in Table 1.

Description	Rated Inlet Steam Condition of turbine			Condensate Pump Rated Flow M3\hr
	Pressure kg\cm2 g	Temp deg C	Flow kg\hr	
RGC Drive Turbine-DHDT	34.5	360	14680	31.3
WGC Drive Turbine-DCU	34.5	360	20520	19

Table-1: Comparison of steam turbine rating v/s condensate pump ratings

Learning: On receipt of material, all the equipment boxes should be marked with Equipment tag, serial No and Unit of installation to avoid any misplacement between same makes and models.

Case Study -3:
Problem: During commissioning of a crude distillation unit (CDU) in a refinery, pumps experienced repeated issues of mechanical seal leakage and shaft seizure after a short run of 12 hours with high mechanical seal flushing fluid outlet temperature.

Figure 3: showing Damaged Stationary face of Mechanical Seal

Root Cause: On dismantling the pumps and thorough inspection, mechanical seal were found damaged due to foreign particles and burning of faces. Temporary blinds installed on cooling water lines to mechanical seal coolers for hydro testing during erection stage were forgotten to be removed. Restriction orifices provided on seal flushing fluid lines were of different sizes than recommended by OEM and some were even without holes.
Learning: Based on these failures, it is recommended to check the auxiliary systems thoroughly as per P&ID diagram before commissioning the machine.

Case Study -4:
Problem: During commissioning of flushing oil pump in CDU of refinery, there was repeated seizure of screws & liner rub.
Root cause: The liners were found damaged due to foreign particles. Temporary strainers installed at inlet were not strengthened properly, and these got damaged after a very short run of 12 hours. There was no pressure differential gauge across the suction strainer.
Learning: All such suction strainers of pumps in the units were strengthened & engineered strengthening procedure was made and got approved. Refer figure 4 & 5 for strengthening of suction strainer. Pressure gauges required to measure differential pressure across the suction strainer were installed. There was no such seizure of collapse of suction strainer after this action.

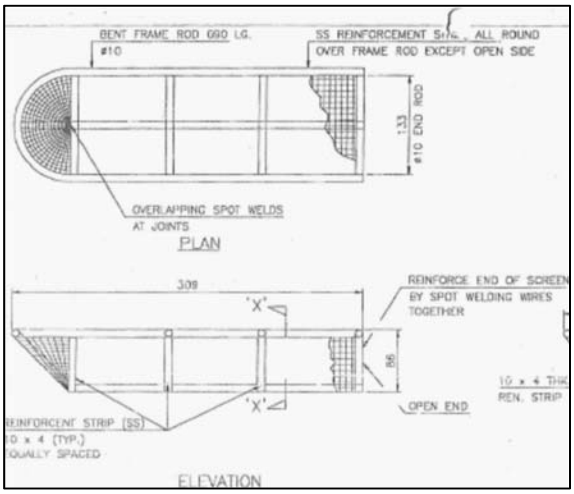

Figure # 4 & 5: Drawing for suction strainer strengthening.

Case study # 5:
Problem: Vibrations in motor side due to soft foot. The common term for machine frame distortion, soft foot is caused when one or more feet of a machine are shorter, longer or angled some way different than the rest of the feet. This non-uniformity causes stress on the machinery when the foot is forced into place by tightening the hold-down bolts. When soft foot is present, the intended machine design and clearances

are compromised. It can cause high vibration levels because the machinery is unduly exposed to excessive wear with each shaft revolution. As shown in Fig 6.

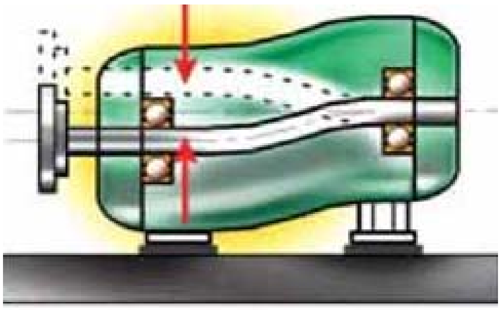

Figure 6: Problem of soft foot in motor

During commissioning of about 1705 rotary equipment in a 9 MMT per annum refinery, none exhibited vibration problem at motors.
Reason: After learning of vibrations due to soft footing, at other refinery complex commissioning. All the motors were checked for soft foot. 28 LT motors, 8 HT motors, soft foot was rectified by grinding and blue matching the pedestals, resulting in smooth operation of machines without vibrations.

Figure 7: Soft foot correction of motors and its blue matching with surface plate

Case Study # 6:
Problem: A petroleum refinery faced severe damage in one of its 35 MW power generation steam turbines within 24 months of commissioning of its captive power plant.
After 24 months of successful and smooth start-up of the machine, an increase in rear end bearing vibration was observed. This vibration trend was continuously increasing while ramping up turbine to base load. Looking at the criticality of machine and severity of vibration, a machine outage was planned for inspection.
Root Cause: Observation after opening of Turbine casing was unexpected. Rotor blades were eroded during a very short run of 24 months and severe damage was observed on 1st and 2nd stage rotor blades. Metal pieces were found from inlet strainers provided before Emergency Shut off Valve
The metal pieces were the effects of not following proper steam blowing procedure and piping inspection during the pre-commissioning stage. As a spare rotor was not available, this resulted in a long outage of machine. Photos of solid material found in the suction strainer is shown in Figures 8 and 9 and blading damage is shown in Figure 9 and 10.

Figure 8 & 9: Solid material found in suction strainer of inlet steam to steam turbine

Figure 9 & 10: Steam turbine rotor blades damage due to solid particle erosion

Learning: Proper and complete steam blowing procedure should be followed in steam piping of Steam turbines. The procedure and checks are discussed later in this tutorial.

Case study # 7:
Problem: High Vibrations were noted in twelve FD/ ID fans of heaters during start up in commissioning. All antifriction bearings of the twelve fans had to be

replaced in short time. Due to the huge effort in doing this, startup of unit got delayed.

Root Cause: Improper preservation of Fans. The plumber block bearing had grease, from which water got separated and caused rusting of the bearings. This occurred during the long storage time of new fans. As per procedures the grease should have been replaced with preservation oil at site on receipt of the fans.

Learning: Proper preservation of equipment as per procedure & inspection of bearings before start up.

Case Study # 8:
Wet gas compressor is one of biggest and critical centrifugal machine in FFCU unit in Refinery. Problem experienced during commissioning: During normal plant operation, the Wet Gas Compressor was not loaded fully; it was observed that whenever 1st stage anti-surge valve closed beyond 25.0 %, flow drastically reduced and Surge Count were detected.
1st stage Anti-surge valve was getting stuck-up at 15.0 %, when the command given from controller/ manual set point for 0.0 % closure.

Figure 11: Foreign body inside valve body

Figure 12: Welding rods & metal pieces removed from valve body

Root Cause: After studying the phenomenon and the surge valve circuit it was found that there is no flow through the anti-surge valve. On opening of anti-surge valve it was found that its cage was badly clogged with foreign material, insulation material. The material was taken out & valve was assembled. It delayed the commissioning of unit. The debris is shown in Figures 11 and 12.

Learning: Generally while flushing of all piping of compressor, the anti-surge valve is not removed. As a result dirt from connected piping during flushing collects in the valve and clogged it. It is highly recommended that before the flushing and cleaning of pipe line of compressor, its anti-surge valve should be removed and a spool piece be fitted in its place. The anti-surge valve should be reinstalled after the piping flushing.

Case Study # 9:
Problem: After commissioning, a 35 MW steam turbine exhibited vibration on front end of bearing housing.
Root Cause: Scratch marks were observed on journal portion of steam turbine rotor shaft and scoring marks on thrust pads and tilting journal bearing pads. (See Figures 13 and 14)
Cause of this was foreign particles in lube oil due to improper lube oil flushing done in the pre-commissioning stage. Flushing was done without thermal shocking.

Figure 13 & 14: Scoring and scratching on journal bearing pads and shaft journal respectively

Learning: Proper flushing with thermal shocking is required before commissioning of centrifugal machinery with hydrodynamic bearings. The best practice is discussed later on in the tutorial.

Case study # 10:
Problem: During commissioning of Motor Spirit block of oil refinery, the Recycle gas compressor (barrel –type centrifugal compressor), exhibited high shaft vibrations at both ends of the machine on restart and attaining its rated speed of 8000 RPM. The unit tripped on high vibration of 125 microns and there was an abnormal noise within the compressor.
Root cause: The spectrum showed peak component at frequency 1X RPM, indicating high unbalance and internal rubbing. The compressor was opened and diaphragm pack was pulled out. The rotor had rubbed with labyrinth seals. A piece of MS plate was stuck in first stage impeller causing unbalance.

The external piece of plate which was lying in compressor suction line downstream of suction strainer was sucked into compressor on start up. This major breakdown caused a delay in unit start up by 5 days. Fortunately a spare rotor and labyrinth seals were available that time.

Learning: It's very important learning to properly clean and inspect suction piping, specifically pipe after the suction strainer up to compressor suction nozzle, with effective methods like rotary head device cleaning (Rotomal Cleaning). It is important to carry out boroscopic inspection of suction piping and inside nozzle of compressor to confirm that no foreign particle exist. Only after this should the suction flanges should be tightened.

Case study # 11:

By learning from the of breakdown of centrifugal compressors in refinery in above case study # 9, care was taken during centrifugal machineries commissioning in 9MMTPA oil refinery. The rotary commissioning engineers executed best practice flushing of compressor and pumps suction line & also carried 100 percent boroscopic inspection of suction piping and suction nozzle of machines, specifically multistage pumps & centrifugal compressors.

Result: Around fifty six centrifugal machines were saved from damage by following above procedure.

Major findings and saves included:

Recycle gas compressor of diesel Hydro treater unit.

On boroscopic inspection inside compressor suction nozzle, piece of welding rod was observed lying inside compressor suction diaphragm.

It was decided to open the diaphragm. On opening the diaphragm small pieces of plates were taken out along with welding rods which was lying inside diaphragm at suction eye of compressor. This foreign material had gone inside the compressor during alignment of suction piping. Gas cutting and welding of suction piping was done in order to make it stress free. These pieces had fallen inside compressor.

This proactive approach saved this compressor from major breakdown which could have happened if compressor had started without the removal of foreign material from compressor.

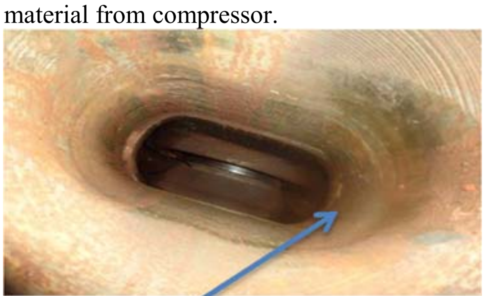

Figure 15: Electrode piece found in suction nozzle of centrifugal compressor during boroscopic inspection

Feed Pump for diesel Hydrotreater unit.

On a multistage centrifugal pump boroscopic inspection before tightening of suction piping with pump, a plate and pieces of gaskets were found inside the suction of pump. These were removed by hanging a magnet in suction as shown in Figure 16 and 17.

Figure 16: Big Metallic plate found inside feed pump (during boroscopic inspection of suction line & inside pump suction), being lifted by magnet

Figure 17: Gasket and aluminum pieces in suction piping

WAYS TO PREVENT DAMAGE & SAVE CENTRIFUGAL MACHINERY

The prevention includes procedures, best practices & inspections to be followed, right from Initial stage of receipt of machines and its preservation to final commissioning.

FORETHOUGHTS DURING EQUIPMENT RECEIPT/ STORAGE

Handling numerous equipment after receipt at site is always a major concern. The following guidelines should be considered

- On receipt of equipment at site, all the received equipment and spares are to be checked as per Goods Delivery Invoices.
- All the equipment boxes should be marked with Equipment tag, serial No and Unit of installation to avoid any misplacement between same make and models.
- All the accessories supplied with equipment should be kept at local storage area with equipment Tag Number and serial Number marked on the boxes.
- For Large centrifugal machines, machines usually are shipped with dry gas seals mounted with machines in locked condition and other accessories mounted on respective skids. However dry gas seals are shipped separately in boxes under nitrogen preservation to avoid soiling or contamination. Positive nitrogen pressure should be assured during storage.
- In some cases, Mechanical Seals are shipped in a dismantled condition and are to be assembled at site. In such cases, a mechanical seal test bench with mandrel is required. All the inverted type seals should be tested on Seal bench prior to mounting on pump. If seal cartridge testing is not

possible, mechanical seals are to be mounted and the complete pump casing should be hydro tested with Mechanical seal. This is required to avoid mechanical seal leak at the time of commissioning/Water Trial.

- It is ***best practice*** to have an in-house mechanical seal refurbishing facility in a workshop where the API mechanical seal cartridges can be refurbished and tested. The workshop should have a lapping machine, monochromatic light, testing of mechanical seal cartridges with dummy shafts, and vacuum testing of seal bellows. Skilled and trained manpower Is also important. Testing equipment is shown in Figure 18

Figure 18: Testing facility for API mechanical seal cartridges with dummy shaft before installing in pumps

- Total Scope of mechanical seal assembly and testing should be accounted for and considered in the project schedule. Mechanical seal assembly and testing should be done prior to shifting the machine to site for erection.
- Bearing housings of all the centrifugal machines and turbines are to be properly lubricated and preserved.
- Bearing housings are to be filled with OEM recommended lube oil with oil cups and breather removed and opening plugged with end plugs to avoid foreign particle ingress into bearing housing and subsequent damage to bearings in event of oil cup damage. This is one of most common mistakes done during erection. We forget to remove oil cups, which get damaged during extensive erection activities around and then dust, moisture and foreign particles enter into bearing housing through these opening. This contaminates oil and damages bearings.
- For Steam turbines, governors are to be filled with OEM recommended fluid.
- For heavy machines or machines with hydrodynamic bearings, shafts are to be rotated on weekly basis to avoid bearing damage and rotor sag etc.
- Dry gas seals, rotors, seal pots, bladders, pressure accumulators are to be kept under positive nitrogen pressure. Pressure gauges are to be fixed on boxes and nitrogen pressure should be checked at fixed intervals.
- Rotors are to be kept in vertical position inside rotor stand at central storage to avoid any damage due to mishandling.
- Preservatives applied on the spares during shipping are to be removed at the time of installation only.

GOOD MACHINERY INSTALLATION PROCEDURES

A good foundation and proper installation is a critical for successful commissioning. This section covers different equipment installation steps and standard practices and provides thumb rules and precautions for these installation steps:

- FOUNDATION PREPERATION: Ensure equipment foundations are as per approved drawings. As a thumb rule, the foundation block should be 3 times of mass of equipment. Usually pockets are left open for inserting the foundation bolts/Anchor bolts. Pocket size should be sufficient to accommodate the foundation bolts with sleeve as well as minor movement of equipment to align with trailing or upstream equipment.

  After installation and commissioning of equipment, equipment foundation should be epoxy painted (coating) to increase its life as well as to protect against soil pollution. Over a period of time, hydrocarbon and water ingress and weakens the foundation
- INSTALLATION OF LEVELLING PAD: Mark the centerline of foundation and center line of equipment. Check for the approximate position of equipment nozzles if applicable. Install the leveling plate using grout on leveling jack screw. If jack screws are provided the base plate can be leveled using jack screw before grout filling.

  If leveling jack screws are not provided, base frame should be leveled on leveling plate directly. In such cases, leveling plate is fixed and leveled first and base frame is mounted on leveling plates.
- EQUIPMENT ERECTION: Usually equipment is shipped on base frame & can be erected as a unit. If base frame is supplied separately, then base frame is to be erected and leveled first.
  - Prior to erection of base plate, foundation bolt to sleeve clearance (Freeness) is to be checked and foundation bolts with sleeve should be inserted into the pocket provided in the foundation block.
  - Base frame is to be leveled on leveling plate or using jack screws to 0.02inch/ft. (0.17mm/m). All feet are to be leveled within 0.002 Inch (0.05mm).
  - If required, the base frame bottom should be painted with epoxy grout primer.

- After leveling of base plate, all foundation pockets should be filled with epoxy grout.
- If the driver is mounted on a separate foundation, rough alignment is to be done prior to foundation bolts pocket filling to ensure alignment with upstream and downstream equipment.
- After curing of epoxy grout, foundation bolts are to be tightened to the desired torque.
- Complete base frame should be filled with epoxy grout through grout holes.
- All pedestal and mounting plates should be blue matched to ensure flatness of pedestals.
- Equipment and driver soft foot is to be checked. The maximum allowable limit is 0.002Inch (0.05mm).
- ***Best Practices*** - Soft foot checks and correction during erection phase itself may eliminate undesired vibration generated during trial run and last minute chaos during equipment trial runs. At the 9MMPTA refinery, proactive soft foot checks and correction on over 2000 machines resulted in no issued induced due to soft foot during commissioning. Alignment of equipment and driver is to be carried out and DBSE (Distance between Shaft Ends) should be maintained as per the coupling drawing. DBSE checking and rough alignment of the machine during foundation bolt pocket filling stage itself, necessary remedial action to be taken to maintain the equipment as per OEM alignment protocol.
- It is usually recommended to place minimum 3 to 5 mm single shim plates on equipment (Both driver and driven) foots to take care of alignment correction during hot alignment and consecutive overhauling after scheduled runs. Typically, steam turbines are kept lower than driven equipment to take care of thermal expansion during operation.

- PIPING INSTALLATION AND ALIGNMENT: Once the equipment grouting and curing is completed, it can be released for piping installation. Less strain imposed on machine casing results in less distortion of running

Figure 19: Damaged Oil Cups during erection stage, source of dirt ingress in bearing housing

Clearances and better machine performance and reliability. The following points should be considered during piping installation:

- All equipment nozzles are to be blinded and equipment is to be kept under nitrogen preservation if possible. This is required to avoid ingress of foreign matter. If usage of standard blind is not possible, thin metal sheets can be used with CAF Sheet gaskets.
- Once piping Installation is completed, nozzles are to be opened and check for excessive strain on equipment nozzles. Ignoring this step can result in poor alignment, high vibration and nozzle cracks.

Figure 20: Damaged Expansion bellow at pump suction due to piping misalignment

- As per acceptance criteria in API 686, pipe flange bolt holes shall be lined up with machinery nozzle bolt holes within 1/16 inch (1.5mm) maximum offset from the center of the bolt holes to permit insertion of bolts without applying any external force to the piping.
- The machine and piping flange shall be parallel to less than 0.001 inch per inch of pipe flange outer diameter up to a maximum of 0.030inch. For piping flange outside diameter less than 10 inch, flanges shall be parallel to 0.10inch or less.
- Machinery Inlet and outlet flanges are separately worked into position to bring the piping flanges into satisfactory alignment with the matching machinery flange. Moving the machinery for achieving piping alignment is not allowed.
- Adjusting the tension of spring hanger or spring support as a method of achieving piping alignment should not be allowed.
- If diamond heating of pipe is to be carried out to achieve piping alignment, piping flange is to be disconnected from machinery to avoid any distortion of machine flange. However for ring heating, piping flange is kept connected to the machine with insulation gasket, as the intention behind ring heating is to force the piping flange to conform to machine flange.

- After finishing piping work, when all temporary supports, guide pins etc. are removed, all spring supports are unlocked and adjusted to their cold set value, ping flanges are to be disconnected from machinery flange and confirmed for final alignment between mating flanges.
- ***Best Practices-*** If both the mating flanges are within acceptable limit. These should be boxed up with Blind plate. Blind plates are to be removed only after water jetting or steam blowing to avoid any ingress of foreign particles and damage of equipment or machine.
- For steam turbines, the flexibility of Inlet and outlet piping is very important to accommodate thermal expansion during start-up. Further details about provision of expansion joints or arrangement of piping, can be found in API 686.

GUIDLINES FOR PIPELINE CLEANING/FLUSHING

Proper flushing and inspection of piping can get rid of half of commissioning related problems. As centrifugal machines, run with very close clearances at very high RPM, even a small foreign particle can have devastating effect. Case study-5 shows the effect of poor steam blowing (Pipeline cleaning) and inspection on one of the steam turbine. It is always recommended to ensure cleanliness of piping before connecting it with machine.

There are many methods of pipeline cleaning like:

1. Cleaning by water
2. Air Flushing
3. Steam Flushing
4. Chemical cleaning
5. Oil flushing
6. Hydro jetting
7. Rotomol (Rotary Head Device) cleaning

Deciding on the suitable cleaning approach is always a critical decision of for the project manager and commissioning team. The decision depends on the type of fluid handled, pipe material and internal wall conditions. Basic guidelines about the listed cleaning methods are as follow:

CLEANING BY WATER: Water flushing is done for pipelines in liquid service. If cleaning by water is unsuitable, other methods will be used. For flushing of stainless steel lines and equipment, DM water shall be used. All Lube Oil Piping are to be blown properly and chemically cleaned/ passivized before lining up with machines.

AIR BLOWING: Air flushing is done for pipes in gas service or low temperature service. If sufficient air is not available, pipes can be cleaned by pressurizing and depressurizing by bursting disc of cardboard or gasket material. Pressure should not increase beyond design pressure. Larger diameter pipe-lines also which cannot be water flushed properly, shall be air blown completely with strong flow of air to clean and dry the lines. The instruments and control valves shall be isolated or removed from the system before flushing. Equipment shall be disconnected to prevent entry of flushed material.

Safety valves and rupture discs are to be isolated or removed during the flushing. Strainer elements to be removed during the flushing operation.

STEAM FLUSHING: Steam Flushing shall be done mainly for steam lines. When cleaning by steam is performed thermal expansion of pipe should be taken into consideration. As Steam blowing/flushing is required for all the steam turbines, steam blowing procedure is explained in detail ahead.

CHEMICAL CLEANING: Critical pipes such as lube oil piping for compressors and suction line of compressor are chemically cleaned by acid and soda solution. The suction line of compressor (from knock out drum to compressor flange) and minimum flow line should be free of grease, rust, and scale. If this is not done, then debris could be ingested resulting in damages relating to packing rings, cylinder liners (in the case of reciprocating equipment) and erosion of the impeller in the case of centrifugal compressors. The lube oil system also should be cleaned thoroughly in order to avoid the possible damage to the compressor bearings by the rust, welding beads etc. The following typical steps may be adopted for cleaning the piping, which does not involve any other material other than carbon steel, in the system. The sequence of activities for chemical cleaning is as follows:

- Flushing with water to remove dirt, dust, loose rust and any foreign matter.
- Degreasing
- Inhibited acid circulation
- Rinsing
- Passivation
- Drying

OIL FLUSHING: Oil Flushing is generally done, for the lube oil circuit after chemical cleaning. The lube oil circuit is normally chemically cleaned and passivized by vendor in his shop and arrives as a sealed unit. At site, oil flushing is carried out to preserve the bearings and other critical parts of centrifugal machines from foreign particles. A detailed lube oil flushing procedure is explained in this tutorial. After lube oil flushing, the old oil should be replaced with fresh OEM recommended oil.

STEAM BLOWING PROCEDURE

- ✓ Remove the piping spool between the turbine trip valve and the isolation block for the turbine inlet. If there is a steam strainer downstream of the block valve, the strainer must be removed.
- ✓ Support inlet piping to withstand the reactive force from the steam blow.
- ✓ Place a covering over the turbine inlet flange. The cover protects the turbine from particles entering during the steam blow, and acts as a device to hold the target.
- ✓ Target mounting methods must ensure that the targets will remain safely attached during the steam blowing process. Actual target material shall be polished SS304 or SS316.
- ✓ Close the inlet valve at the header and open the inlet valve at the turbine.
- ✓ Start the steam flow and allow the piping to warm. After the piping is warm, increase the steam flow to 50% of the desired load. If everything is normal without significant leakages from temporary joints, continue ramping the steam to reach the desired flow rate for the designed blow conditions.
- ✓ It is preferred to use low pressure high velocity steam blowing due to lower noise steam consumption. Quench water is added to control the noise level of exhaust steam thereby making the vicinity area workable. A comparison of low pressure high velocity continuous blowing and puff blowing is shown in Annexure-F.
- ✓ The blow conditions must be maintained so that a Cleaning Force Ratio (CFR) of 1.0 is achieved throughout the targeted steam blow path.

$$CFR = m^{2}_{SB} V_{SB} / m^{2}_{max} V_{max}$$

Where,
m^{2}_{SB} = Mass Flow Rate during Steam Blow
m^{2}_{SB} = Mass Flow Rate at Max Operating Conditions
V_{SB} = Specific Volume at Steam Blow Conditions
V_{max} = Specific Volume at Max Operating Condition

- ✓ Required flow rate, pressure and temperature to achieve CFR are to be calculated for each section prior to the start of steam blowing.
- ✓ Blow steam through the system without any backpressure at flow rates as close to maximum until no particles can be observed from the line. Several cycles of blowing may be required to remove the particles. Thermal Shocks during steam blowing can assist the process.
- ✓ In thermal shocks, steam temperature is reduced to 30Deg C above saturation temperature (for example if Saturation Temperature is 100DegC, Steam temperature is to be reduced up to 130DegC). Cooling is achieved by adding BFW into the steam header using a temporary attemperator. The temperature is again increased to highest limit and maintained for at least 1 hour. A minimum of three thermal shock cycles is to be performed.
- ✓ Close the header valve once no particles are seen and securely attach the polished target on the target support.
- ✓ Open the steam header valve and blow for at least 15 minutes. Close the header valve and inspect the target.
- ✓ Acceptance criteria for piping cleanliness is based on the following:
  a. An acceptance target will have no raised pits.
  b. An acceptable target will have less than three pits in any square centimeter of the target, and no pit shall be larger than 1 millimeter.
  Steam blowing shall be repeated until the acceptance criteria have been met.
  Figure 21 shows steam blowing activity.

Figure 21: steam blowing activity with silent blowing. Does not stop Work in vicinity.

OIL FLUSHING PROCEDURES

- ✓ Oil flushing is carried out to remove dirt from the system by loosening it from the inside of the system or by dissolving it in the flushing oil. Dirt which is picked up by the flushing oil will be caught in the fine mesh installed in the return line and can be removed. Oil Flushing procedure is provided below. Before charging the lube oil inside the tank, it is important to ensure that the lube oil tank & run down tank are thoroughly cleaned.
- ✓ All loose foreign material such as scale, sand, weld splatter particles and cutting chips shall be removed. The inside of the interconnecting piping should be wire brushed where accessible. Thereafter, the interconnecting piping shall be thoroughly cleaned before installation by air or steam blowing .

- ✓ Lube Oil piping is to be connected and for initial flushing temporary bypass piping is to be connected for bearing housings and Seal Oil supply. The scheme is to be validated by the machinery OEM.
- ✓ Orifices, probes and other flow restrictions must be removed for cleaning and flushing to obtain optimum velocities. All removed items shall be tagged and properly store for reinstallation.
- ✓ All the pressure gauges except lube oil pump discharge pressure gauge, pressure switches and instrument connections shall be isolated.
- ✓ All the PSVs shall be removed and blinded during the flushing.
- ✓ Ensure Motor power connection is provided and, that the auxiliary and emergency oil pumps are ready for use to circulate lube oil.
- ✓ The entire lube oil circuit is divided into different circuits/loops so as to make the flushing more effective. Flushing of successive loops shall be started after the completion of flushing of preceding loop.
- ✓ Fill the tank with enough oil (up to min. level shown on the level gauge) i.e., up to the level such that the pump suction is fully immersed during flushing. Note that after starting the flushing oil, the level will drop inside the tank so make-up oil arrangement should be ready.
- ✓ Ensure that the lube oil tank heater is commissioned and maintains the temperature between 60-70 deg C.
- ✓ Make temporary hose connections / jump overs across the bearing housing as per the identified scheme connecting the supply lines to return header with fine mesh (100 mesh plain weave, stainless steel) in-between.
- ✓ Install fine mesh (100 mesh plain weave, stainless steel) in the lube oil return line just before the tank as identified in the scheme.
- ✓ In the first circulation, filter elements should not be installed. Once the clarity of lube oil improves, filter elements should be installed properly seated in the filter housing. Ensure filter element commissioning spares are available.
- ✓ At the time of lube oil flushing through bearing, the dry gas seal should not be in place but if it is already installed then a nitrogen/Instrument air purge shall be provided as a separation gas at design pressure.
- ✓ Sufficient venting of the oil cooler & filters shall be done while taking inline to ensure no air pockets is left.
- ✓ Once the filter element is installed, periodically check the pressure drop across the oil filter. When the pressure drop becomes too high (As per OEM recommendation) change over to the clean filter element. Remove and replace the dirty filter element.
- ✓ Initially fine wire mesh should be checked after ½ hr. of circulation for accumulation of dirt/corrosion products. Carry out the flushing of lube oil piping through the fine mesh into the return header for 12 hours for each loop. Periodically strike the piping in an attempt to loosen any foreign material. Vary the oil temperature during the flushing process from hot to cold and vice versa a number of times.
- ✓ Stop the lube oil pump after 12 hours of circulation, allow for oil to drain back in to the tank and check the fine mesh for collected particles. Repeat flushing till no particles are observed visibly and no grittiness in felt by touch.
- ✓ The system shall be considered to be clean when the return line mesh found to be free from any foreign particles.
- ✓ A Centrifuge/ online cleaning system shall be used for cleaning the lube oil in the reservoir during flushing.
- ✓ On the completion of the flushing, lube oil sample shall be taken from the reservoir bottom and checked for water content and dirt contamination. Depending on the results oil shall be conditioned or replaced with fresh oil.

OTHER PIPING CLEANING REQUIREMENTS

- o If piping has hard deposits/Scale or connected to equipment, it should be water jetted using Rotary Head device (Rotomal).
- o ***Best Practices***-The piping between Inlet strainer and equipment Inlet flange is to be water jetted with a Rotary head device (Rotomal). (Figure 22)

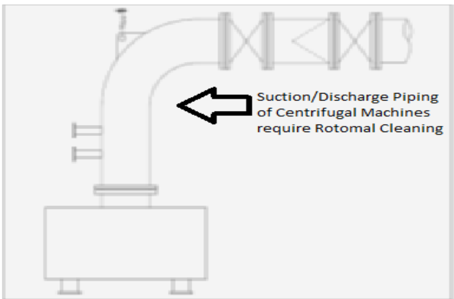

Figure 22: Suction piping after strainer up to pump nozzle – Rotomal cleaning is a must.

- o This section is of major concern as it is downstream of the strainer. it
- o Precaution is to be taken during de-blinding of machine flanges, as all the foreign particles in the piping will accumulate above the blinds during flushing or blowing. Immediate spools are to be dropped and cleaned before de-blinding.

PRE-COMMISSIONING ACTIVITIES: Pre-commissioning activities include final checks to get the confidence of safe start up. Efforts made during Pre-commissioning and commissioning are key to a successful startup.

For centrifugal compressor, precaution should be taken during hydro-testing of casing drain and vent lines. These lines are usually welded at site and hydro tested to ensure the integrity of welded joint. During hydro-testing a key hazard is ingress of water into the casing due to negligence or error which may cause severe damage to the machine and such mistakes could result in machine dismantling and dry gas seal replacement

- ***Best Practices***- Thorough Boroscopic inspection of suction line and suction nozzle of centrifugal machinery to be carried to find out any foreign material inside the machinery.

Figure 23: Metallic Rod Found During Boroscopic Inspection

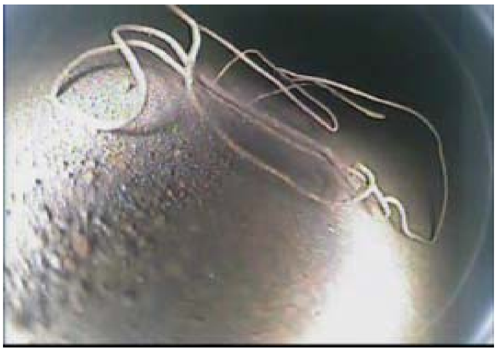

Figure 24: Metallic Wire pieces and scale observed during boroscopic inspection of suction Piping

- After completion of boroscopic inspection and rectification of all findings. Piping is to be finally connected to the machines.
- This is the time when all the PCC and MCC panels are energized for "No Load" trial of motors Is done.
- Before energizing any electrical panel, proper Lock out Tag out Procedure is to be developed and enforced in order to avoid any accident.
- All respective motor tags are to be marked on LCS Panel, Name Plate and PCC/MCC panel to avoid any incident during energization.
- Final assembly of all piping with new filters, RO and all as per marked P&ID is to be done. ** please reword this**
- Oil relief valves and pressure control valves calibration is to be ensured. These valves are to be calibrated on site with the lube oil pump running. Calibration is to be confirmed at maximum operating temperature such as some oil with Normal viscosity above 200CST at 40deg C, shows a vast variation in viscosity (Pressure Drop) above 70deg C.
- Mechanical seals are to be unlocked and to be installed if kept separately.
- All bearing housings are to be installed with all accessories and charged with fresh oil.
- Final alignment of machines with piping is to be carried out as per alignment protocol.
- Machines are to be installed with temporary strainers at inlet, however all these strainers are to be strengthened to avoid any damage due to strainer mesh damage itself.
- Prior to commissioning, OEM Representatives should be at site.

MINIMUM REQUIREMENT OF WORKSHOP FOR SUCCESSFUL CENTIFUGAL MACHINERY COMMISSIONING

To deal with exigencies during commissioning, the following facilities should exist:

- Seal room with Mechanical Seal testing facility complying to API682 and Lapping Machine- ***Best Practices***
- Repair Shop with balancing machine, boring machine, and Universal Drilling machine, lathe machines with different bed sizes and minimum mandatory machines set up to facilitate minor repair and fabrication during commissioning.
- PSV/PVRV Calibration/ test Bench
- In-situ drilling tapping and machining facilities with skilled manpower.

COMMISSIONING ACTIVITIES

- Machine Specific "Do's and Don'ts" are to be prepared as per OEM manual (See Annexure-A for an example).
- Machine operating parameters and Performance curves should be collected and kept on display on local and remote control panels.
- Start Up/Commissioning Checklists are to be prepared. (Sample Checklists attached)
- All Erection, Installation, Pre-commissioning checklists are to be collected for all connected auxiliary systems and to be checked for pending action items before commissioning the machine.

- Obtain completed checklists for the foundation, piping, grouting, and alignment activities for the particular equipment train to be started.
- Basic cleaning of the piping system should already been performed to remove such items as weld rod, hard hats, and lunch buckets, out of the lines in a new system prior to flanging up to the new equipment. Additional cleaning of the system shall be provided for steam turbine inlet piping and positive displacement compressor piping.
- Turbine inlet piping should be free blown clean and verified as clean using a target method as mentioned in steam blowing.
- For positive displacement compressor inlet piping, 100-mesh start-up screens are to be installed.
- Control valves and instrument loops shall be loop functional tested before start-up. Set points for controllers, switches, and transmitters shall be obtained from the user, set, and verified.
- All gauges must be calibrated.
- Piping and instrument diagrams of the system shall be checked to verify that the unit piping, controls, and instrumentation are built per design.
- Useful items that a rotating equipment engineer should carry during commissioning includes:
    - Measuring Tape
    - Checklist
    - Pocket Diary
    - Vibration Pen
    - Small Torch
    - Small Allen key set
    - 6” filler Gauge
    - 6” Measuring Scale
    - Permanent Marker Pen
    - Seal plan synopsis
    - Standard Torqueing Value Chart
- All cooling water piping to the machinery shall be flushed and then connected to the machinery prior to operation.
- All temporary blinds installed during hydro testing and flushing are to be removed and verified as per P&ID. All RO are to be checked for orifice size.
- Purge the machinery for a minimum period of time to minimize foreign material.
- When purging equipment with steam, verify that seals with elastomeric sealing components will not be heated above their allowable temperature limits.
- Driver pre-rotation checks shall be made to verify that the installation is correct, safe, and that no damage will occur to the equipment on the initial start.
- Motor solo runs are made to determine if any problems exist with the motor operation as soon as possible in order to provide maximum time for correction.
- TURBINE SOLO RUN: Turbine drive solo should be made as soon as possible after the steam system has been commissioned in order to provide maximum time to correct any turbine problems.
    - Verify that piping system is complete and cleaned.
    - Verify that the vendor instructions are followed properly.
    - Inlet strainers, either permanent or temporary, should be installed in the inlet line upstream of the trip and throttle valve. The integral strainer to the trip and throttle valve is not sufficient as a start-up strainer.
    - The exhaust line should be opened before the inlet line to avoid over-pressuring the turbine exhaust casing.
    - Verify turbine seal leak-off piping is open and that carbon rings (or other sealing system) are installed, if required.
    - Verify that the turbine cooling water lines are open.
    - Ensure that required pressure and temperature gauges are installed.
    - Verify that a working speed indicator system is available to determine the turbine speed. If a handheld unit is to be used, verify access to signal generator.
    - Exercise the turbine trip and throttle valves prior to admission of steam. Follow user-specified instructions for trip system function verification before start-up.
    - Follow user-specified instructions for start-up.
    - Verify that proper governor oil level has been achieved for all governor oil systems.
    - There may be critical speeds on larger turbines that will need to be avoided during start-up. Determine if there are any speed ranges to avoid for each turbine and agree with operations as the ramp speed through these areas.
    - Turbines with carbon seals need a break-in period where the speed is raised and then reduced to properly wear in the carbons. Vibration should be monitored during this period. When no jumps in vibration are noticed with increasing speed, then the seals are probably properly seated.
    - If the turbine speed starts to increase after minimum governor speed is reached and the governor does not control, then investigate the governor control system for problems.
    - Record vibration data on the data sheet periodically as agreed until the operating conditions have stabilized. Record minimum and maximum governor speed and trip speed.

- o Check bearing temperatures and bearing vibrations during the coast-down after trip. The turbine should coast down smoothly and not come to an abrupt halt.
- o Adjust trip set point per vendor's instructions if trip speed is not acceptable. Turbine trip speed will be given by the turbine manufacturer. Multiple trips within a specified speed range may be required for particular installation.

- Verify alignment data has been recorded, including any pre stretch or compression of the coupling spacer.
- Install the coupling spacer to the required shaft end spacing (DBSE). Line up match marks if provided. Verify non spacer coupling DBSE is correct before bolting coupling flanges. For grease-packed or oil-lubricated couplings, follow coupling vendor instructions for lubrication and bolting Torque coupling bolts to the required torque. Typically the torque values are for oil-lubricated bolts. Torque bolts to 50 percent of required torque in a pattern across the diagonal. After all bolts are torqued to 50 percent then torque all bolts in a similar sequence to 100 percent of required torque.
- Machinery shall be turned over by hand after coupling to ensure freedom of operation.
- On cartridge seal assemblies, verify the Locking collars are tight and that the locating cams have been locked out of position so as not to come in contact with the rotating shaft.
- Install coupling guard. Verify all jack screws used for alignment have been loosened so as to eliminate any residual load from the jack screws that might affect alignment.
- Check all the ready to start parameters as per OEM Instructions and as marked in Do& Don'ts (Start-Up Sequence) prepared for machine.
- Water/Nitrogen Trial run of all the machines should be done as far as possible.
- During initial start-up of the equipment, operating conditions such as inlet and outlet pressures, temperatures and flow rates shall be recorded.
- Equipment performance data is to be matched with original performance curve and any deviation should be recorded.
- Vibration signatures shall be obtained for all bearings.
- For motor drives, motor current shall be obtained.
- All connections shall be inspected for leaks.
- Record that proper start-up procedure has been followed.
- Piping supports/spring hangers shall be adjusted accordingly when the system is in service at operating temperature.

CONCLUSION:

From the above discussion & experiences the following conclusions can be drawn.

Centrifugal machinery represents the most critical equipment in the process industry refinery and it drives the commissioning schedule. Common mistakes and carelessness made from the receipt of material through commissioning can cause damage and delay and can affect the refinery start up schedule. Issues from bearing damages to compressor/ steam turbine internal damages can be experienced.

It is possible to mitigate these problems by following the best practices, procedures and check lists provided in this paper.

To conclude the following best practices should always be considered:

- Soft foot correction of electrical motors must be done by blue matching thus avoiding vibration related problems in motors.
- Ensure the availability of a fully functional, state of art workshop providing continuous support for maintenance, machining, blue matching, testing etc. The workshop should have in House capability to refurbish API mechanical seals.
- Hydraulic torqueing and tensioning of critical & hydrocarbon joints must be done to avoid hydrocarbon leakages.
- Mechanical run test of compressors / Water trials of Pumps should done before admitting hydrocarbon in line thus avoiding hydrocarbon leaks.
- Ensure support engineers trained by OEMs and on the job thus having in house capability to resolve major rotating equipment maintenance problems in critical areas.
- Conduct boroscopic inspection of suction pipe line and inlet nozzles before commissioning.
- Conduct hot alignment of hot pumps.

REFERENCES:

- API RECOMMENDED PRACTICE 686: Recommended Practices for Machinery Installation and Installation Design, 2nd Edition.
- API Standard 612, Petroleum, Petrochemical and Natural Gas Industries - Steam Turbines - Special-purpose Applications, 5th Edition
- API Standard 611, Petroleum, Chemical and Gas Industry Services- General Purpose Steam Turbines, 5th Edition
- API Standard 617 Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services, 7th Edition

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ANNEXURE-A

DHDT RGC machine Do's & Don'ts During commissioning / Trip cases

Compressor End:

1. Ensure the nitrogen blanketing inside the LUBE OIL TANK.(Nitrogen Pressure : 200mmWC)
2. Before starting lube oil circulation ensures that the barrier gas supply is in line. Barrier supply header pressure should not be less than 2.1kg/cm2. And DE & NDE barrier supply gauge should be above 0.45kg/cm2.
3. Before taking gland steam ensure the nitrogen blanketing in compressor bearing housing is in line. The nitrogen pressure should be 200mmWC.
4. Compressor casing to be charged through Primary seal line to avoid particle carry over to primary seal ID and face hanging.
5. Before barring Ensure the primary and secondary seal gas is in line.
6. Ensure Primary gas seal PDCV....... minimum of 0.04 kg/cm2 to be maintained during speed ramp up , also keep the PDCV by pass valve in open condition till differential pressure through discharge is generated . (During Nitrogen trials keep always by pass open condition).
7. Primary seal filters to be drained to CBD once , every day.
8. Always charge compressor through equalization line of isolation valves, never open UV and isolation valves suddenly to avoid rolling of rotor with gas flow. During this case if barring lever is in engaged mode , may damage turbine rotor and bearing
9. Keep casing drain in open condition after trip & closure of UV to remove the moisture
10. Barring to be continued till casing temperature is 80Degc
11. In case of emergency trip of power failure , Nitrogen pressure drop - Stop AOP and line up EOP , barring to be done manually once in 15 Minutes for ½ Rotation.
12. Keep compressor primary & secondary seal drain condition after machine is stopped or tripped to remove the condensate.
13. Suction UV of compressor to be kept opened till compressor comes to stand still.

Turbine end

1. Before taking gland steam ensure the nitrogen blanketing in turbine bearing housing is in line. The nitrogen pressure should be 200mmWC
2. Lube oil header pressure 2- 2.5 Kg/cm2, control oil pressure 8 Kg/cm2 should be healthy.
3. Lube oil temperature should be b/n 40 to 45^{0}c.
4. Vacuum pulling to be done after gland steam supply and putting turbine on barring
5. Level in hot well should be maintained before startup to 50%.
6. Turbine inlet steam line to be heated to 320^{0}c before startup(ESV in closed condition)
7. Gland steam supply should be 0.05 kg/cm^2 before startup and 0.04 kg/cm^2 in running.
8. Startup valve should be fully open till ESV Below pressure becomes 8 Kg/cm2 and ESV U/s pressure becomes Zero , also Ensure ESV position in open condition physically

ANNEXURE-B
Centrifugal Compressor Commissioning Checklist

Plant: **Equipment Category: IR Centrifugal Compressor** **Checklist No:** **Equipment Tag No:**	**Equipment Name:** **Make :** **Model :** **Sr.No.**

S. N.	**Check Points**	**Operation**	**Mechanical**	**Electrical**	**Instrumentation**
1	Name plate/tag number on the Compressor, Motor, lube oil pump and its drive motor is verified.				
2	Handover-Takeover checklist for the Compressor verified.				
3	Enusre Format-5 is completed for the system before commissioning the equipment.				
4	Ensure equipment conformity with vendor P & ID, GA drawings, Isometrics				
5	Direction of check valves and other directional valves are as per P & ID				
6	Cleanliness of suction filter house elements and lube-oil filters ensured				
7	Verify the proper fitment of filter elements .				
8	Suction line downstream of the filter needs to be blown with air before box-up so as to ensure the cleanliness.				
9	Spring support lock removed and cold setting is as per specification				
10	Discharge bellow shall be unlocked before commissioning.				
11	Spring support lock removed and cold setting is as per specification				
12	Ensure Differential pressure measurement PDT is inline				
13	All studs/bolts and gaskets are as per specified size, material and length are installed				
14	Cleanliness of lube oil pump suction strainer verified				
15	Safety valve calibration and testing verified				
16	Check for presence of directional arrows on NRV's, directional valves and control valves and their proper installation				
17	Ensure Lube oil is of correct specification and is in good condition.				
18	Ensure Prelube oil pump drive motor solo run taken, DOR verified.				
19	Flushing / cleaning of folllowing pipelines completed as per approved procedure / scheme. Protocol signed for cleanliness and lines boxed up				
	Suction and discharge piping				
	Lube oil circuit flushed using dedicated lube oil flushing procedure, sight glass ensured for cleanliness and leak freeness				
	Seal Gas piping				
	Drain piping				
	Cooling Water lines				
	Instrument air				
20	Operability of valves, etc. verified				
21	Bearing housing flushed. For pumps with dedicated lube oil circuit, lube oil circuit flushed as per lube oil flushing procedure				
22	Appropriate Lubricant applied/filled				
23	Cleanliness, leak freeness of oil cup/sight glass/level gauge etc verified				
24	Lube oil level in the pump/ console verified				
25	Free rotation of pump and driver verified				
26	The driven equipment is coupled to driver and coupling guard is fitted				
27	Barrier/buffer fluid filled in seal pot				
28	In case of Plan 53, Bladder charged with nitrogen to specified pre-charge				

	pressure.				
29	All utilities like cooling water, steam etc. charged				
30	Check all blinds are removed				
31	Instrumentation system verified.				
32	Electrical system verified.				
33	Instrument calibration and set points verified				
34	All protective devices are on line				
35	Machine condition monitoring devices installed and functioning checked (If applicable)				
36	All field instruments are in line and working properly				
37	In case of Steam turbine driver, governor flushed and linkages verified for free movement				
38	Equipment Insulation / Painting completed				
39	DOR of driver verified & solo-run of driver. In case of Steam turbine overspeed trip verified.				
40	Piping gaskets as specified (Gasket audit of equipment and associated piping)				
41	All studs/bolts as per specified size, material and length and there are no short bolting				
42	Pump suction valve open and pump has charged as per specified procedure in case of hot service				
43	Hot alignment completed (Record the readings and attach with this checklist)				
44	Piping supports verified				
45	Spring hangers lock removed and cold setting is as per specification				
46	Base plate is clean and drain is clear.				
47	Ensure cleanliness and house keeping around the equipments.				
48	Trial run & Checks conducted ● Process Conditions (Pressure, Temperature, Flow) ● Vibrations & "G" Values ● Bearing Temperatures ● Motor current, turbine steam pressures and flows ● Seal inlet/ outlet temperature ● No leaks ● No abnormal noise				

Remarks :

ANNEXURE-C

Centrifugal Pump Commissioning Checklist

Plant: **Equipment Category: Centrifugal Pump** **Checklist No:** **Equipment Tag No:**		**Equipment Name:** **Make :** **Model :** **Sr.No.**			
S. No.	**Check Points**	**Operation**	**Mechanical**	**Electrical**	**Instrumentation**
1	Verify correct name plate tag number of the pump	*	*		
2	Handover-Takeover checklist for the pump verified.	*	*	*	*
3	Enusre Format-3 is completed for the system (for water trial) and Format-5 is completed for the commissioning with the hydrocarbon.	*	*	*	*
4	Ensure equipment conformity with vendor P & ID, GA drawings, Isometrics	*	*	*	*
5	Direction of check valves and other directional valves are as per P & ID	*	*		
6	Cleanliness of suction strainer and lube-oil filters ensured	*	*		
7	Fitment of Strainer for proper seating verified.	*	*		
8	Cleanliness of Suction line downstream of strainer ensured (If possible)	*	*		
9	Strainer provided withfine mesh # 40 screen.	*	*		
10	Operability of valves, etc. verified	*			
11	Bearing housing flushed. For pumps with dedicated lube oil circuit, lube oil circuit flushed as per lube oil flushing procedure	*	*		
12	Appropriate Lubricant applied/filled	*	*		
13	Cleanliness, leak freeness of oil cup/sight glass/level gauge etc verified		*		
14	Lube oil level in the pump/ console verified	*	*		
15	Free rotation of pump and driver verified		*		
16	The driven equipment is coupled to driver and coupling guard is fitted		*		
17	Barrier/buffer fluid filled in seal pot	*	*		
18	In case of Plan 53, Bladder charged with nitrogen to specified pre-charge pressure.	*	*		
19	All utilities like cooling water, steam etc. charged	*	*		
20	Check all blinds are removed	*			
21	Instrumentation system verified.				*
22	Electrical system verified.			*	
23	Instrument calibration and set points verified	*			*
24	All protective devices are on line	*	*	*	*
25	Machine condition monitoring devices installed and functioning checked (If applicable)	*	*		*
26	All field instruments are in line and working properly				*
27	In case of Steam turbine driver, governor flushed and linkages verified for free movement		*		
28	Equipment Insulation / Painting completed	*	*		
29	DOR of driver verified & solo-run of driver. In case of Steam turbine overspeed trip verified.	*	*		

30	Piping gaskets as specified (Gasket audit of equipment and associated piping)	*	*		
31	All studs/bolts as per specified size, material and length and there are no short bolting	*	*		
32	Pump suction valve open and pump has charged as per specified procedure in case of hot service	*			
33	Hot alignment completed (Record the readings and attach with this checklist)		*		
34	Piping supports verified		*		
35	Spring hangers lock removed and cold setting is as per specification		*		
36	Base plate is clean and drain is clear.	*	*		
37	Ensure cleanliness and house keeping around the equipments.	*	*		
38	Trial run & Checks conducted ● Process Conditions (Pressure, Temperature, Flow) ● Vibrations & "G" Values ● Bearing Temperatures ● Motor current, turbine steam pressures and flows ● Seal inlet/ outlet temperature ● No leaks ● No abnormal noise	*	*		

*** indicates responsibility of the concerned department for the respective department followed by signature.**
Remarks :

ANNEXURE-D

Checklist for Centrifugal Compressor Handover

Plant: **Equipment Category : Rotary Blower/Compressor**		**Equipment Tag No:** **Equipment Name:**			
S. No.	**Check Points**	**Operation**	**Mechanical**	**Electrical**	**Instrumentation**
1	Name plate details of compressor and motor recorded and verified as per drawing	*	*		
2	Ensure equipment conformity with vendor P & ID, GA drawings, Isometrics and check for all the protocals signed during the erection of the equipment.	*	*		
3	Check the accessibility for compressor for routine operation & maintenance		*		
4	Check the compressor suction/discharge lines are installed & stress free		*		
5	Check the compressor seal flushing plan as per vendor drawing.	*	*		
6	Check correct grade of oil in system as per vendor recommendation		*		
7	Check the compressor base plate bolts are tightened after complete curing & grout is done		*		
8	Compressor suction strainer installed with 100 mesh as per specification and leak tightness verified.	*	*		
9	Check the area is cleaned of debris & proper house keeping is done	*	*		
10	Check the compressor lube oil drained is routed to proper draining system as specified	*	*		
11	Check cooling water connection to Seal oil coolers.	*	*		
12	Ensure availability of shim (at least 2 mm) under motor but number of shims should not be more than 5 nos.		*		
13	Check for the soft foot ,if found rectification is to be done.		*		
14	Flange parallelism and separation for the pump suction / Discharge flange checked. (Record the readings and attach with this checklist)		*		
15	With and and Without Piping Alignment checked (Record the readings and attach with this checklist)		*		
16	Ensure erection of all related instruments and adjustment of trip and alarm setting.	*	*		*
17	Coupling Spacer and all coupling bolts assembled and coupling guard installed.		*		
18	Oil cup/sight glass/level gauge etc. should be in position and bearing housing should be filled with correct grade of Lube oil after flushing.	*	*		
19	Cleanliness, leak freeness of oil cup/sight glass/level gauge etc verified	*	*		
20	Free rotation of rotary blower and driver verified.	*	*		
21	All utilities like cooling water etc. are connected to the system.	*	*		
22	Instrumentation / MCMS (if applicable) system verified.				*
23	Electrical system verified.			*	
24	Equipment Insulation / Painting completed	*	*		
25	Auxilary systems such as seal system,etc are installed	*	*		

26	Motor alignment bolts shall be in position.		*		
27	Check the condition and fitment of suction strainer with 100 mesh.	*	*		
28	Cleanliness of Suction line downstream of strainer ensured (If possible)	*	*		
29	Check the blower drain & vent system as per P&ID.	*	*		
30	Check the electrical equipments earthing connection.			*	
31	Check Equipment Tag. No. and lube oil details are painted on the equipment Foundation	*	*		
32	General observation - any damage / crack of components, loose parts, missing fasteners etc	*	*	*	*
33	Ensure cleanliness and house keeping around the equipments.	*	*	*	*

*** indicates responsibility of the concerned department for the respective department followed by signature.**
Remarks :

ANNEXURE-E
Checklist for Centrifugal Pump Handover

Plant: **Equipment Category:**	**Equipment Tag No:** **Equipment Name:**

Sr. No.	Check Points	Operation	Mechanical	Electrical	Instrumentation
1	Verify correct name plate tag number of the pump	*	*		
2	Ensure equipment conformity with vendor P & ID, GA drawings, Isometrics	*	*		
3	Full grouting of base plate with specified grouting done.	*	*		
4	Ensure availability of shim (at least 2 mm) under motor but number of shims should not be more than 5 nos.		*		
5	Check for the soft foot, if found rectification is to be done.		*		
6	Flange parallelism and separation for the pump suction / Discharge flange checked. (Record the readings and attach with this checklist)		*		
7	With and Without Piping Alignment checked (Record the readings and attach with this checklist)		*		
8	Ensure erection of all related instruments and adjustment of trip and alarm setting.	*	*		*
9	Coupling Spacer and all coupling bolts assembled and coupling guard installed.	*	*		
10	Oil cup/sight glass/level gauge etc. should be in position and bearing housing should be filled with correct grade of Lube oil.	*	*		
11	Cleanliness, leak freeness of oil cup/sight glass/level gauge etc verified		*		
12	Free rotation of pump and driver verified.	*	*		
13	All utilities like cooling water, steam etc. are connected to the system.	*	*		
14	Instrumentation / MCMS (if applicable) system verified.				*
15	Electrical system verified.			*	
16	Equipment Insulation / Painting completed	*	*		
17	Auxiliary systems such as seal system, lube oil system are installed	*	*		
18	Seal Lock washer shall be in position.	*	*		
19	Motor alignment bolts shall be in position.		*		
20	Check bearing housing breather is in position.		*		
21	Check the condition and fitment of suction strainer.	*	*		
22	Cleanliness of Suction line downstream of strainer ensured (If possible)	*			
23	Check the pump drain & vent system as per P&ID.	*	*		
24	Check the drainage system of pump base plate	*	*		
25	Check the electrical equipment earthing connection.	*		*	
26	Check Equipment Tag. No. and lube oil details are painted on the equipment Foundation	*	*		
27	General observation - any damage / crack of components, loose parts, missing fasteners etc.	*	*	*	*
28	Ensure cleanliness and housekeeping around the equipment.	*	*		

*** indicates responsibility of the concerned department for the respective department followed by signature.**
Remarks :

ANNEXURE-F

Comparison of Continuous and Puff Blow- Steam Blowing

Criteria	Continuous Blow	Puff blow	Remarks
Steam Velocity	The system is designed and **blown at maximum velocity all over the line**.	Full system **not** subjected to Max velocity. Max velocity achieved close to outlet of temp. pipe only.	Higher velocities used in continuous blow facilitates better cleaning and removal of contaminants
Flexibility	Flexible	Uncontrolled	
Cleanliness	Superior cleaning over the entire line under consideration.	May be localized close to exit point.	
Effective Cleaning force ratio. (CFR)	Assured >1.1 calculated based on Max operating conditions throughout the blow all over the line.	May be reached at selected points only for few very short duration.	The duration of Max CFR in Puff blow is inadequate for cleaning deeper inside the line and hence cleaning cannot be guaranteed.
Noise	Around 90 db	Exceed 130 db	Facilitates working in nearby areas when our continuous blow is in progress.
Duration	Duration is closely defined due to engineered process, typically 12 to 48 Hrs. max.	Unknown duration typically requires 40+ blows over 10+ days	CB Significantly reduces commissioning time.
Thermal Cycling	On line without stopping the blow.	Blow interrupted	In CB, thermal cycling is achieved in 1-1.5 Hrs reducing cleaning time.
Target Insertion	Safe on line pneumatic inserter, uninterrupted blow		Saves much time for multiple targets for better QA.
System Loading & Stress.	LP high Vel. blow. Hence min. stress & load on boiler and supports. No anchors required.	Boiler subjected to high stresses and piping requires strong expensive anchoring, QOV, Rated Temporary Piping etc.	Minimum effect on Boiler life on using continuous blow.
Cost Saving	The cost of executing the continuous steam blow is considerably less when all factors linked with the boiler turbine system are taken into consideration,		